J. Soils and Crops 32 (2) 296-300, December 2022
ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)

ROOT CHARACTERISTICS, NODULATION AND YIELD OF LENTIL (*Lens esculenta* MOENCH) UNDER INTEGRATED NUTRIENT MANAGEMENT

Reetu Swarnkar[1], Janmejay Sharma[2] and Deepak Bairagi[3]

ABSTRACT

The present study was carried out during *rabi* 2020-21 at the research farm, College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh to study the effect of integrated nutrient management on root characteristics and nodulation in lentil (*Lens esculenta* Moench). The lentil crop (cv. RVL-30) was grown under 10 different nutrient management treatments laid out in a factorial randomized block design with 3 replications. The recommended dose of fertilizers (RDF) for lentil crop was 20: 40: 20 kg ha^{-1} N: P_2O_5: K_2O. The crop was sown with a seed rate of 30 kg ha^{-1}. In order to study the root characteristics and nodulation, periodic observations on root length, root biomass, root:shoot ratio and nodulation were recorded. The study revealed that the application of 50% RDF + FYM @ 2.5 t ha^{-1} significantly influenced the root length, root biomass and nodulations in lentil at various growth stages as compared to rest of the treatments. Similarly, the application of 50% RDF + FYM @ 2.5 t ha^{-1} recorded significantly higher root: shoot ratio at maturity. However, the root: shoot ratio exhibited non-significant difference in all the treatments at 30 DAS and 60 DAS. The grain yield of lentil was also found significantly higher under the treatments those showed higher root characteristics and nodulation. Thus, the application of integrated nutrient management favors the growth and nodulation of root in lentil which reflected in significantly higher grain yield.

(Key words: lentil, root biomass, root length, nodulation, integrated nutrient management)

INTRODUCTION

Lentil (*Lens culinaris* Medick.) is a nutritious food legume that belongs to the Fabaceae family and is sometimes referred to as an old crop for modern times. It's a nutrient-dense grain legume that grows in temperate climates and contains a seed with greater dietary protein (340-346 g), carbohydrate (65.0 per cent), and calories (340-346 g) than other legumes. Aside from its nutritional value, lentils have a wide range of agricultural applications that contribute to the long-term viability of agriculture. Despite having superior nutritional quality to cereals and being well adapted to local conditions, including marginal soil, farmers have been ignoring lentil cultivation in recent years, and its area has lowered and its productivity has fallen far short of its potential, jeopardising the food and nutrition security of millions of smallholder and other farming communities (Kumar *et al.,* 2010).

The total area under lentil crop is approximately 6.58 million hectares, with an output of approximately 7.59 million tonnes and an average yield of 1153 kg ha^{-1} (Anonymous, 2019). In India, lentil output reached an all-time high of 16.07 Lakh tons from 15.54 Lac ha of land, with a productivity of 1034 kg ha^{-1}, the greatest yield level ever (Anonymous, 2018). Lentil occupied about 5.96 Lac ha in Madhya Pradesh in 2017-18, with a yield of 6.79 Lac tons and a productivity of 1139 kg ha^{-1} (Anonymous, 2018).The low yield of lentils is primarily due to its cultivation on poor and marginal soils with declining soil fertility and unpredictable environmental conditions, which have arisen as a result of intensive land use without proper replenishment of plant nutrients, particularly where high yielding varieties of cereals are cultivated using unbalanced doses of mineral fertilisers with little or no organic recycling.Deep and prolific root system has been reported as the sign of healthy and productive soil as it enhances the ability of a plant to extract water from deeper layers of soil and supplies the nutrients (Gahoonia *et al.,* 2007). Rapid root and canopy development are essential for the successful establishment of a crop. Vigorous root development is essential for seedling survival under conditions where the soil surface dries up rapidly but sufficient soil moisture remains available in deeper zones (Kumar *et al.,* 2012). Studies of crop root systems has lagged behind than that of above-ground plant characteristics, and have been less extensively studied in legumes than in cereals.With regard to food legumes, limited information is available on seedling root and shoot attributes in lentil (Kumar *et al.,* 2012; Idrissi *et al.,* 2015). Considering the

1. P.G. Student, Dept. of Agronomy, RajmataVijayarajeScindiaKrishiVishwaVidyalaya (RVSKVV), Gwalior – 474002 (E-mail: reetuswarnkar93@gmail.com)
2. Scientist, Dept. of Agronomy, RVSKVV, Gwalior – 474002
3. P.G. Student, Dept. of Environmental Science, RVSKVV, Gwalior – 474002

above facts, present study was conducted to determine the variability of root and shoot attributes at an early and late growth stage of lentil under integrated nutrient management practices in central India.

MATERIALS AND METHODS

Study area and climate

The field experiment was conducted at the Research Farm, College of Agriculture, RVSKVV, Gwalior (M.P.) during the *rabi* season of 2020-21. Gwalior is situated in the northern tract of M.P., enjoying subtropical climate with extreme hot about 46° C in summer and minimum temperature 10° C in the winter season. It is located at the latitude of 26°3' N, longitude 74°4' E and altitude of 208 m above the sea level.

Meteorological observations

The meteorological observations recorded during the crop growth period are presented in Fig. 1. The minimum and maximum temperature during crop growth period ranged from 5.0-17.2°C and 21.3-39.3 °C, respectively. The average maximum and minimum temperature recorded during the crop growing season was recorded 27.6 °C and 9.6 °C, respectively. The relative humidity during crop growth season ranged from 56.0-86.4%. The average relative humidity recorded during the crop growing season was 73.8%. The total rainfall received during the crop growth period was 7 mm (Fig. 1).

Initial soil properties

The soil samples before commencement of the present investigation were collected from 0-15 cm depth and analyzed for physic-chemical properties. The field soil was sandy clay loam (Sand- 59.50%, silt- 18.45% and clay- 22.05%) having soil pH 7.71, electrical conductivity 0.41 dSm^{-1} and organic carbon 4.2 g kg^{-1}. The soil available N, P_2O_5 and K_2O were found 169.3 kg ha^{-1}, 14.02 kg ha^{-1} and 195.84 kg ha^{-1} respectively.

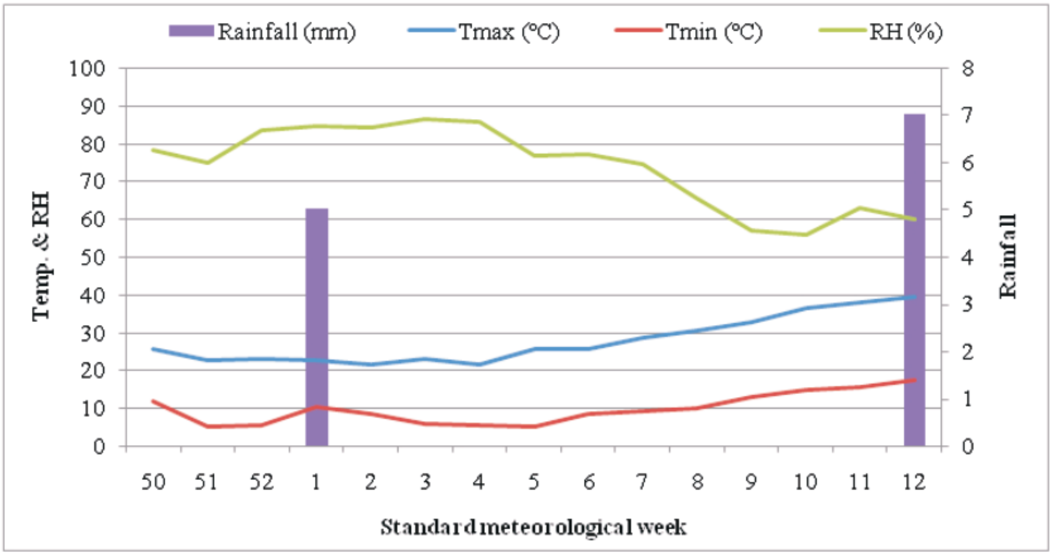

Figure 1. Meteorological observations during crop growth period

The field experiment

The experiment was conducted at the Research Farm of Department of Agronomy, College of Agriculture, Gwalior during the *kharif* season of 2020-21. The ten different treatments *viz.,* 125% RDF, 100% RDF, 75% RDF + Rhizobium, 75% RDF + PSB, 75% RDF + Rhizobium + PSB, 50% RDF + FYM @ 2.5 t ha^{-1}, 50% RDF + PSB, 50% RDF + Rhizobium, 50% RDF + PSB + Rhizobium and Control were laid out in a FactorialRandomizedBlock design (FRBD) with three replications. The lentil crop (cv.RVL-30) was grown under these treatments with a seed rate of 30 kg ha^{-1}.The recommended dose of fertilizers (RDF) for lentil crop was 20: 40: 20 kg ha^{-1} N: P_2O_5: K_2O.

The experimental field was prepared properly after pre-sowing irrigation. When soil became workable, the field was ploughed with disc plough followed by two tillage operations by cultivators. The recommended doses of P and K were applied as a basal dose, whereas half quantity of N fertilizer was applied at the time of sowing and remaining dose was applied as top dressing after first irrigation. Well decomposed FYM was added to the plots as per treatment one day before sowing. *Rhizobium* and PSB were applied as a seed treatment @ 5 g kg^{-1}. Further, half dose of nitrogen was applied as top dressing after first irrigation. The sowing was carried out as per treatments by broadcasting keeping row to row distance of 30 cm.

Root study

Root length (cm)

Five average plants from each plot were randomly selected and marked/tagged for root length. Root length of crop plant was recorded in centimeter with the help of meter scale at various physiological stages of plant growth e.g. 30,60 and at harvesting time in each plot separately.

Root biomass (g)

For root biomass, crop plants were uprooted from the soil with the help of *khurpi*, root of plants washed with flowing tap water to remove the adhered soil. After that root samples were first dried in sun and then in oven at 60±2°C for about 24-72 hours till constant weight were achieved. After drying, the samples were weighed with electrical balance for root biomass and it was averaged to g plant^{-1}. Dry biomass was recorded from five randomly selected locations in each plot at 30, 60 DAS and at harvest.

Root: shoot ratio

The shoot: root ratio was computed by dividing the shoot length by root length. It was recorded from five randomly selected locations in each plot at 30, 60 DAS and at harvest.

Root nodulation

The total number of nodules plant^{-1} was counted at 50 % flowering stage. Five plants were selected randomly in sample rows of each plot and uprooted carefully. The soil mass embodying the roots of the plants was washed off with water and total as well as effective root nodules were counted to record average number of nodules plant^{-1}.

Statistical analysis

All data related to pre and post harvest studies of crop collected were analyzed statistically by using the analysis of variance technique (Fisher, 1958). Data thus computed was subjected to Fisher' s analysis of variance for judging the effect of various treatments.

RESULTS AND DISCUSSION

Root length

The data regarding root length of lentil at various growth stages under various treatments are presented in Table 1.The root length of lentil was found significantly influenced under different INM treatments at 30 DAS, 60 DAS and at maturity.At 30 DAS the longest root length was measured in 50% RDF + FYM @ 2.5 t ha^{-1}(6.73 cm) and 75% RDF + Rhizobium + PSB (6.73 cm) and the next effective treatments were125% RDF, 100% RDF, 75% RDF + PSB, 75% RDF + Rhizobium, 50% RDF + PSB + Rhizobium, 50% RDF + PSB and 50% RDF + Rhizobium (5.60 cm, 5.53 cm, 5.53 cm, 5.47 cm, 5.40 cm, 5.13 cm and 4.99 cm, respectively). The shortest root length was recorded in control (3.90 cm). At 60 DAS, the longest root length (11.53 cm) was measured in 50% RDF + FYM @ 2.5 t ha^{-1} which was at par with 75% RDF + Rhizobium + PSB (11.47 cm). Application of 50% RDF + PSB + Rhizobium,125% RDF, 75% RDF + PSB, 100% RDF, 75% RDF + Rhizobium, 50% RDF + PSB and 50% RDF + Rhizobium were the next effective treatments in sequence. The shortest root length was recorded in control (7.33 cm). Similarly,the root length of lentil was significantly influenced under different INM treatments at maturity. Among the various treatments, the longest root length was measured in 50% RDF + FYM @ 2.5 t ha^{-1} (12.50 cm) which was close to 75% RDF + Rhizobium + PSB (12.33 cm) and both were superior over 50% RDF + PSB + Rhizobium,125% RDF, 75% RDF + PSB, 100% RDF, 75% RDF + Rhizobium, 50% RDF + PSB and 50% RDF + Rhizobium.The soil available P plays an important role in vigorous root development in plants (Kumar *et al.,* 2009). Hassan *et al.* (2018) studied root length of 20 different lentil genotypes and found that the root length ranged from 5.350-25.167 cm with a mean value of 8.645 cm. These findings are in conformity with the results of present investigation.

Root biomass

The various INM treatments at 30 DAS substantially influenced root biomass of lentil (Table 2). The maximum root biomass was found under 50% RDF + FYM @ 2.5 t ha^{-1} (0.051g) which was statistically equivalent to 75% RDF + Rhizobium + PSB (0.049g), 125% RDF (0.049g),100% RDF (0.046g) and 75% RDF + PSB (0.044g),75% RDF + Rhizobium, 50% RDF + PSB + Rhizobium, 50% RDF + PSB and 50% RDF + Rhizobium. The minimum weight of root biomass was recorded in control (0.022g). At 60 DAS, among the different treatments, the maximum root biomass was weighed up under 50% RDF + FYM @ 2.5 t ha^{-1} (0.104g) which was at par with 75% RDF + Rhizobium + PSB (0.098g), 125% RDF (0.088g),100% RDF (0.087g) and 75% RDF + PSB (0.084g). The minimum root biomass was achieved under control (0.041g). Similarly, the root biomass was significantly influenced by different INM treatments at maturity. Among the different INM treatments, significantly higher root biomass was recorded under 50% RDF + FYM @ 2.5 t ha^{-1} (0.107g) which was at par with 75% RDF + Rhizobium + PSB (0.102g) and both the treatments were superior over 125% RDF, 100% RDF, 75% RDF + Rhizobium, 50% RDF + PSB + Rhizobium, 75% RDF + PSB, 50% RDF + PSB and 50% RDF + Rhizobium. The lowest root biomass was recorded in control (0.043g). The soil available P plays an important role in vigorous root development in plants (Kumar *et al.,* 2009). Hassan *et al.* (2018) studied root biomass of 20 different lentil genotypes and found that the root biomass ranged from 0.020-0.094 g plant^{-1} with a mean value of 0.057 g plant^{-1}. In present investigation also the root biomass ranged from 0.022 g plant^{-1} to 0.107 g plant^{-1}.

Root nodulation

The data regarding effect of nutrient management on root nodulation at 50% flowering are presented in Table2. The studied treatments significantly influenced the root nodulation in lentil. Application of 50% of the recommended dose of NPK in combination with 2.5 t ha^{-1} FYM brought about maximum number of root nodules (11.55 plant^{-1}) followed by 75% RDF + Rhizobium + PSB. Both the treatments were at par with each other and significantly superior over other treatments. The next effective treatments were 125% RDF,100% RDF, 75% RDF + Rhizobium, 75% RDF + PSB, 50% RDF + PSB + Rhizobium, 50% RDF + PSB, and 50% RDF + Rhizobium. The lowest number of nodules was counted in control (7.47 plant^{-1}), which was significantly inferior as compared to other INM treatments.

Table 1. Influence of integrated nutrient management on root length

Treatments	Root length (cm) at		
	30 DAS	60 DAS	Maturity
125% RDF	5.60	9.87	11.05
100% RDF	5.53	9.67	10.83
75% RDF + Rhizobium	5.47	9.47	10.60
75% RDF + PSB	5.53	9.83	10.95
75% RDF + Rhizobium + PSB	6.73	11.47	12.33
50% RDF + FYM @ 2.5 t ha^{-1}	6.73	11.53	12.50
50% RDF + PSB	5.13	9.23	10.33
50% RDF + Rhizobium	4.99	9.10	10.20
50% RDF + PSB + Rhizobium	5.40	10.53	11.67
Control	3.90	7.33	8.00
SE(m)±	0.21	0.31	0.12
CD at 5%	0.61	0.91	0.35

Table 2. Influence of integ rated nutrient manag ement on root biomass

Treatments	Root biomass (g $plant^{-1}$)			Root nodules $plant^{-1}$
	30 DAS	60 DAS	Maturity	At 50% flowering
125% RDF	0.049	0.088	0.091	10.64
100% RDF	0.046	0.087	0.090	10.33
75% RDF + Rhizobium	0.038	0.072	0.087	10.00
75% RDF + PSB	0.044	0.084	0.075	9.77
75% RDF + Rhizobium + PSB	0.049	0.098	0.102	11.15
50% RDF + FYM @ 2.5 t ha^{-1}	0.051	0.104	0.107	11.55
50% RDF + PSB	0.034	0.071	0.073	9.57
50% RDF + Rhizobium	0.033	0.067	0.069	9.42
50% RDF + PSB + Rhizobium	0.037	0.081	0.083	9.77
Control	0.022	0.041	0.043	7.47
SE(m)±	0.002	0.007	0.004	0.14
CD at 5%	0.006	0.020	0.011	0.42

Table 3. Influence of integrated nutrient management on root: shoot ratio

Treatments	Root: shoot ratio at			Grain yield (kg ha^{-1})
	30 DAS	60 DAS	Maturity	
125% RDF	0.433	0.302	0.322	899
100% RDF	0.435	0.310	0.318	856
75% RDF + Rhizobium	0.429	0.305	0.312	840
75% RDF + PSB	0.455	0.325	0.342	835
75% RDF + Rhizobium + PSB	0.496	0.340	0.355	940
50% RDF + FYM @ 2.5 t ha^{-1}	0.472	0.328	0.354	1008
50% RDF + PSB	0.555	0.321	0.323	730
50% RDF + Rhizobium	0.438	0.323	0.330	715
50% RDF + PSB + Rhizobium	0.440	0.338	0.357	814
Control	0.469	0.289	0.300	485
SE(m)±	0.036	0.012	0.009	23.72
CD at 5%	-	-	0.026	70.49

Water and temperature stresses can suppress nodule formation and function in legumes, consequently causing a decrease in N fixation. Lentil has a remarkable ability to maintain nodules until water stress is severe and to recover nodule growth following moisture restoration. The soil nutrient availability also plays significant role in nodule formation. MacMillan *et al.* (2021) studied spatial and temporal development of the root system of Guar (*Cyamopsis tetragonoloba* [L.] Taub.) leguminous crop and reported root nodules in the range of 8.3-48.0 plant^{-1}. The root nodules of lentil observed in present study also confirm these findings.

Root: shoot ratio

That root: shoot ratio of lentil found significantly influenced under various treatments at 30 DAS, 60 DAS and at maturity (Table 3).The data revealed that the root: shoot ratio exhibited non- significant difference in all the treatments at 30 and at 60 DAS. The ratio ranged from 0.429 to 0.555 at 30 DAS and 0.289 to 0.340 at 60 DAS.At maturity, the application of 50% of the recommended of NPK combined with FYM @ 2.5 t ha^{-1}resulted in maximum root: shoot ratio which was at par with 75% RDF + Rhizobium + PSB (0.355), 50% RDF + FYM @ 2.5 t ha^{-1} (0.354) and75% RDF + PSB (0.342). The lowest root: shoot ratio was recorded in control (0.300).The soil available P plays an important role in vigorous root development in plants (Kumar *et al.,* 2009). Hassan *et al.* (2018) studied root:shoot ratio of 20 different lentil genotypes and found root:shoot ratio in the range of 0.382-1.974 with a mean value of 0.736.

Grain yield

The data regarding the grain yield of lentil under various treatments are presented in Table 3. The data revealed that the grain yield of lentil found increased significantly with the application of fertilizer either individually or together with FYM and bio fertilizers compared to the control. The application of 50% RDF combined with FYM @ 2.5 t ha^{-1} (1008 kg ha^{-1}) produced significantly maximum grain yield which was statistically at par with the application of 75% RDF + Rhizobium + PSB (940 kg ha^{-1}). Similarly, treatments 125% RDF,100% RDF, 75% RDF + Rhizobium, 75% RDF + PSB, 50% RDF + PSB + Rhizobium, 50% RDF + PSB and 50% RDF + Rhizobium also produced significantly more grain yield ha^{-1}over control (485 kg ha^{-1}).It has been observed that the treatments showed positive effects in improveing root characteristics and nodulation and reflected significantly higher yield. Yadav *et al.* (2017) found significantly higher yield of maize crop under integrated nutrient management *viz.,* the application of 100% N through neem coated urea. Jadhav *et al.* (2018) studied the integrated nitrogen management and reported significantly higher grain yield of *kharif* sorghum (*Sorghum bicolor* L.) under the application of 100% N through neem coated urea + 10 kg humic acid ha^{-1} (granular). The application of 75% NPK + FYM@ 7.5 t ha^{-1} + PSB (5 kg ha^{-1}) + Azatobacter (4 kg ha^{-1}) also reflected as beneficial treatment with respect to the higher grain yield of maize in irrigated area of Punjab significantly (Singh *et al.,* 2021). The results of present study also showed significantly higher yield of lentil under integrated nutrient management.

The presence of readily available plant nutrients, growth enhancing substances, and number of beneficial organisms as well as antibiotics, vitamins, and hormones, may account for FYM's favourable effect on soil. Thus, nutrients had a positive influence on the production of larger cells with thinner cell walls, as well as their contribution to cell division and cell elongation, which improved vegetative growth and, as a result, increased root length, biomass, nodulations and root:shoot ratio under integrated nutrient management especially with the application of chemical fertilizers in combination with FYM which reflected in terms of grain yield of lentil crop.

REFERENCES

Anonymous, 2019.Crops and livestock products, Food and agriculture data.Food and Agriculture Organization of the United Nation.http://www.fao.org/faostat/en/.

Anonymous, 2018.Districtwise Production & Yield – Cropwise new (2016-17 to 2018-19).www.mpkrishi.org

Fisher, R.A. 1958. Statistical method for research workers. Oliver and Boyd, Edinburgh

Gahoonia, T. S., R. Ali, R.S. Malhotra, A.Jahoor and M.M. Rahman, 2007.Variation in root morphological and physiological traits and nutrient uptake of chickpea genotypes. J. Plant Nutr. **30**(6) : 829-841.

Hassan, S., P.A. Sofi, N.S. Khuroo, K. Rehman and M.A. Bhat, 2018.Natural variation for root traits, morphological and yield parameters in lentil (*Lens culinaris* M.). Bull. Env. Pharmacol. Life Sci. **7** : 80-84.

Idrissi, O., C. Houasli, S.M.Udupa, E. De Keyser, P. Van Damme and J. De Riek, 2015.Genetic variability for root and shoot traits in a lentil (*Lens culinaris* Medik.) recombinant inbred line population and their association with drought tolerance. Euphytica, **204** (3) : 693-709.

Jadhav, R.R., S.P. Bainade, N.D. Jadhav, V.S. Hivare and N.D. Parlawar, 2018.Effect of integrated nitrogen management on growth, yield and economics of *kharif* sorghum (*Sorghum bicolor* L.). J. Soils and Crops.**28** (2) : 407-412.

Kumar, A., Reena,B. Nandan, J. Kumar and B.S.Jamwal, 2010. Response of large seeded lentil to seed rate, phosphorus and FYM application in sub-tropical kandi-belt of Jammu and Kashmir. J. Food Leg., **23**(1): 44- 46.

Kumar, J., P.S. Basu, E.Srivastava, S.K.Chaturvedi, N.Nadarajan and S. Kumar, 2012. Phenotyping of traits imparting drought tolerance in lentil. Crop Pasture Sci. **63**(6) : 547-554.

Kumar, V., V. N. Dwivedi and D.D.Tiwari, 2009.Effect of phosphorus and iron on yield and mineral nutrition in chickpea. Ann. Plant Soil Res. **11**:16-18.

MacMillan, J., R. Shrestha, C.B. Adams, P.O. Hinson and C.Trostle, 2021. The root system of guar: Spatial and temporal analysis of root and nodule development. Ann. Appl. Biol. **179** (3) : 278-287.

Singh A., R. Pratap and J. Singh, 2021. Response of maize (*Zea mays* L.) to integrated nutrient managment under irrigated area of Punjab. J. Soils and Crops, **31** (2) : 237-241.

Yadav, A.M., V.G. Nagdeote, V.G. Raut and I.M. Nagrare, 2017.Effect of integrated nitrogen management on growth, yield and economics of maize. J. Soils and Crops, **27** (1) : 178-182.

Rec. on 10.02.2022 & Acc. on 17.02.2022